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B-Lifetime Measurements at the Tevatron

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B-LIFETIME MEASUREMENTS AT THE TEVATRON

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Abstract

During the run period from May 1992 to begin of June 1993 the Collider Detector at Fermilab (CDF) has recorded $\approx$ 21.4 pb^{-1} of $p\overline{p}$ collider data at $\sqrt{s} = 1.8$ TeV. For this run the detector had been upgraded which significantly enhanced its b-physics capabilities. The upgrades include a high precision Silicon VerteX detector (SVX) which enables CDF to reconstruct the decay vertex and decay length of b-hadrons. In this article we report on several measurements of the lifetime of b-flavored hadrons. The determination of the average b-lifetime using inclusive $J/\psi's$, the measurement of the $B^{\pm}$ and B^{0} lifetimes by reconstructing exclusive final states including a J/ψ or $\psi(2S)$ and a measurement of the B^0_s meson lifetime exploiting the decay: $B_s \rightarrow l\nu D^+_s \rightarrow l\nu\phi\pi^+ \rightarrow l\nu K^+K^-\pi^+$

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1 Introduction

During the 1992-93 run (Run 1A), which lasted from the 12th of May 1992 to the first of June 1993, the Collider Detector at Fermilab (CDF) managed to record $\approx$ 21.4 pb^{-1} of $p\overline{p}$ collider data at $\sqrt{s} = 1.8$ TeV to tape.

The b-lifetime measurements described in this article are the first ones reported from a hadron collider experiment. They demonstrate that it is possible to access the large $b\bar{b}$-cross section at hadron machines ($\sigma(b\bar{b}) = 6.5 \pm 2.2$ μb for $|\eta| < 1.$ and $P_t(b) > 7.5$ GeV/c at $\sqrt{s} = 1.8$ TeV [1]) and to achieve a precision comparable or better than at e^+e^- machines which up to now dominate the field.

In the absence of a sophisticated trigger which selects events including displaced vertices there are basically just two ways to obtain clean b-enriched samples at hadron collider experiments. One is to trigger on events including high p_T leptons, while the other is to trigger on $J/\psi \rightarrow \mu^+\mu^- X$ events. As we will see in the following sections we have collected large data sets of inclusive lepton and dilepton events. The J/ψ sample for example consists of approximately 80000 events after background subtraction where about 20% come from b-decays.

The CDF detector has been described in detail elsewhere [2]. For the 1992-93 collider run, a silicon vertex detector (SVX) has been installed [3]. The SVX consists of 4 layers of silicon-strip detectors with r-ϕ readout, including pulse height information. The pitch between readout strips is 60 μm, resulting in a spatial resolution of 13 μm. The first measurement plane is 2.9 cm from the interaction point, leading to an impact parameter resolution of ~ 10 μm for high momentum tracks. Figure 1 shows one of the two SVX barrels. Each barrel has a length of approximately 25 cm. A new central muon extension (CMX) system installed in 1992 extends the muon coverage to be used in the trigger to a pseudorapidity $|\eta| < 1$ compared to $|\eta| < 0.65$ previously, where $\eta = -\ln(\tan(\theta/2))$.

2 Measurement of the inclusive B-lifetime using $J/\psi's$.

We report here a high statistics measurement of the inclusive b-lifetime determined from a sample of $B \rightarrow J/\psi X \rightarrow \mu^+\mu^- X$ decays corresponding to 10.1 ± 0.7 pb^{-1}. With the large b production cross section in $p\overline{p}$ collisions it is now possible to obtain statistical uncertainties of $\sim$ 4% for this mode, which occurs with a product branching ratio $BR(B \rightarrow J/\psi X) \cdot BR(J/\psi \rightarrow \mu^+\mu^-) \approx 7.7 \times 10^{-4}$ [4].

CDF uses a three-level trigger system. At Level 1 the particular trigger selecting the events used in this analysis required the presence of 2 charged tracks in the central muon chambers. For the inclusive lifetime measurement we restricted ourselves on muon pairs in the central muon system which covers $|\eta| < 0.65$. For this system the trigger efficiencies are well measured and could be used in computer simulations necessary to obtain correction factors (see below).

Level 2 required that at least one of the muon tracks match a charged track in the Central Tracking Chamber (CTC) found by the Central Fast Track (CFT) processor [5]. The CFT selected tracks with $P_t > 2.5$ GeV/c. The level 3 software trigger required the invariant mass of the dimuon system to be between 2.8 and 3.4 GeV/c^2.

To reduce the background from fake muons, the following muon selection cuts were applied:
1) the distance between the track in the muon chamber and the extrapolated CTC track was calculated in both the transverse and longitudinal planes. In each view, the difference was required to be less than 3.0 standard deviations (σ) from zero (where a standard deviation is calculated as the quadratic sum of the multiple scattering and measurement errors);
2) the energy deposited in the hadronic calorimeter by each muon was required to be greater

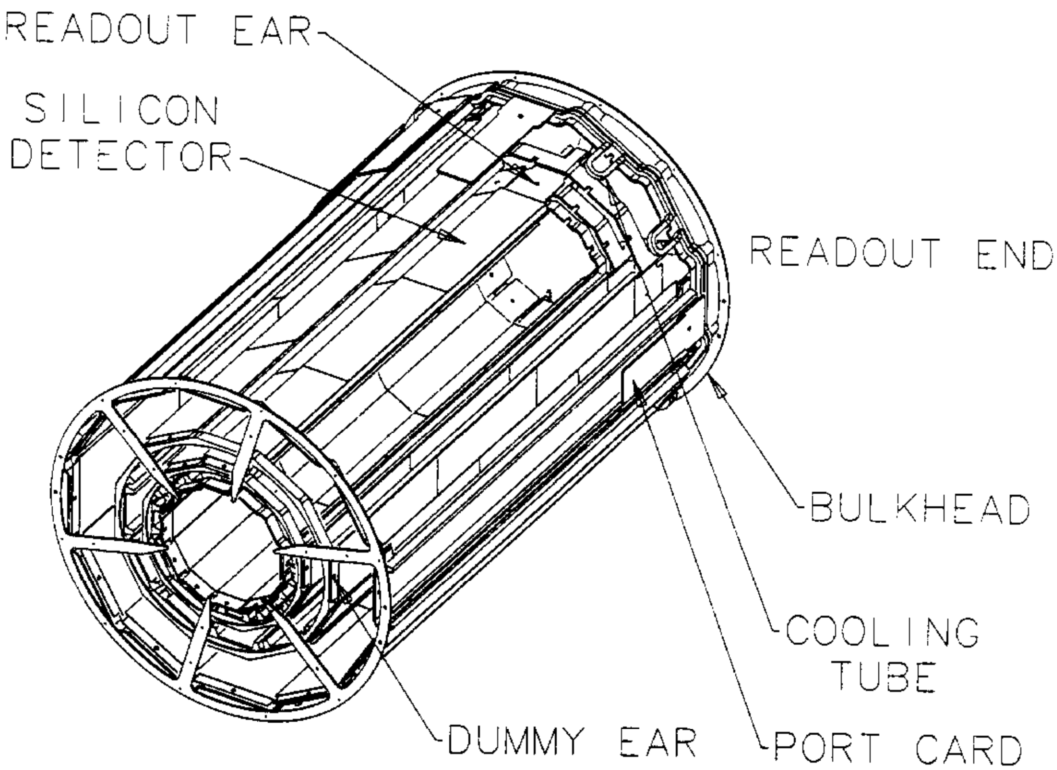

Figure 1: *Schematic view of one of the two SVX barrels.*

than 0.5 GeV, corresponding to the presence of a minimum ionizing track;
3) the reconstructed P_t of at least one of the muons was required to be > 2.5 GeV/c.
We required both muons to be reconstructed in the SVX with at least three out of the four possible hits. To ensure that the J/ψ decay vertex was well measured, strict track quality cuts were imposed on the sample [6]:
1) all SVX track residuals were required to be less then 4 σ;
2) SVX tracks where one or more hits were assigned to more than one track were removed;
3) SVX tracks with hits with total charge more than 4 times the charge deposited by a minium ionizing particle were removed;
4) the two muons were required to come from a well-measured vertex;
5) the calculated error on the transverse decay length $\sigma_{L_{xy}}$ (see definition of L_{xy} below) was required to be < 150 μm (compared to the mean value of $\sigma_{L_{xy}} \approx 60\mu m$);
6) for each muon the χ^2 for SVX hits was required to be less than 20 for 4 d.o.f.

After applying the above cuts, a sample of 5667 events remained in the J/ψ mass range, defined to be ± 50 MeV/c^2 around the world average value of the J/ψ-mass ($3.0969\ GeV/c^2$). After background subtraction we find 5350 $J/\psi \to \mu^+\mu^-$ candidates with a mass resolution of 16 MeV/c^2.

Sideband regions are defined to have invariant mass from 2.9 to 3 GeV/c^2 and 3.2 to 3.3 GeV/c^2. These sidebands were used to determine the lifetime distribution shape of the background under the J/ψ signal. Figure 2 shows the invariant mass distribution of the selected events.

For each J/ψ in the sample, a two dimensional decay distance L_{xy} was calculated. L_{xy} is the projection of the vector $\vec{X}$ pointing from the primary to the secondary vertex onto the

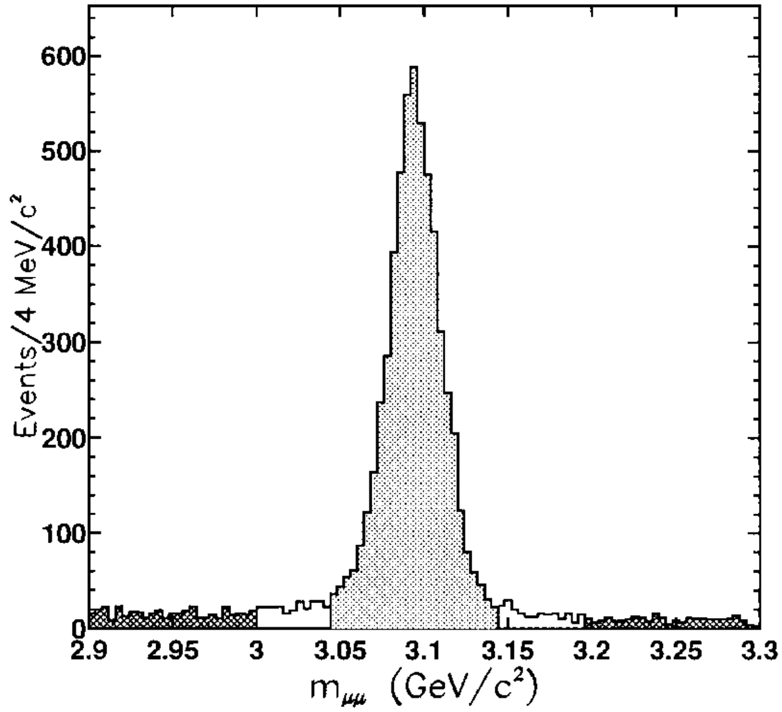

Figure 2: *Invariant mass distribution of two oppositely charged muons as selected for the inclusive lifetime measurement. The grey-hatched area indicates the J/ψ signal region and the cross-hatched areas show the sideband regions.*

transverse momentum of the J/ψ:

$$L_{xy} = \frac{\vec{X} \cdot \vec{P}_t^{\psi}}{|P_t^{\psi}|}$$

Here the decay vertex position is obtained from the vertex-constrained fit to the two muon tracks. The primary vertex is approximated by the average beam position, determined run-by-run by averaging over many events. The transverse profile of the beam is circular and has a rms of approximately 36-38 μm.

To convert the transverse decay length into a lifetime the relativistic quantity $(\beta\gamma)_B$ of the b-hadron must be determined. Since the J/ψ's selected by the dimuon trigger carry most of the B momentum, the $(\beta\gamma)_\psi$ of the J/ψ is a good first approximation for $(\beta\gamma)_B$. A correction factor F as shown in Figure 3a) was determined from Monte Carlo as a function of the transverse momentum of the J/ψ. F varies only weakly over the P_t range of the J/ψ sample and is approximately 0.86. The P_t-distribution of our J/ψ-sample is shown in Figure 3b) where $\lambda > 200\mu m$ was required to ensure that all J/ψ's come from b-decays.

Thus the best estimate of the proper time of the B is given by:

$$\lambda = L_{xy} \cdot \frac{M_\psi}{p_t^\psi F(p_t^\psi)}$$

To obtain F the momentum spectrum of the b-quarks was generated using the QCD calculation from reference [7]. To estimate the systematic uncertainties in modeling this cross section we compared the QCD predictions with simple power law distributions producing softer or harder spectra than the data or the QCD prediction. The b-quarks were then fragmented using the Peterson fragmentation function [8] where the fragmentation parameter and its uncertainty ($\epsilon = 0.006 \pm 0.002$) have been taken from [9]. The b-hadrons were then forced to decay into $J/\psi + X$. The J/ψ spectrum in the B rest frame was obtained from the experimental results of ARGUS and CLEO [10]. We also used their results [11] , to set bounds for the polarization when modeling the decay $J/\psi \to \mu^+\mu^-$. The resulting muon decays were passed through a computer simulation of the CDF detector and trigger.

In order to extract the B lifetime from the λ distribution, we fit to 3 sources of dimuon events in the J/ψ invariant mass region:

(i) J/ψ's from B decays. This part is parameterized as a Gaussian convoluted with an exponential. The fit parameter f_B gives the fraction of J/ψ coming from B-decay.

(ii) J/ψ's directly produced in $p\bar{p}$ collisions, or resulting from the decay of intermediate states which are sufficiently short-lived that their decay vertex is indistinguishable from the primary vertex (eg. χ_c's). This part is parameterized with a Gaussian resolution function.

(iii) 'fake' J/ψ's coming from processes whose invariant mass falls accidentally in the J/ψ mass window. These events include dimuons from Drell-Yan production, double semileptonic b-decays, meson decays-in-flight and hadron punch-through. The shape of the contribution is obtained by fitting the sidebands. This fit is parameterized as the sum of a central Gaussian and left-side and right-side exponentials with different slopes. Since the dimuon sample contains events from sequential b-decays ($b \to c\mu\nu \to s\mu\nu\mu\nu$), the λ distribution is expected to be asymmetric. The background fraction, f_{BGR}, is also determined from the sidebands and is not a fit variable.

Figure 4b) shows the λ distribution in the signal region. The result of an unbinned likelihood fit to the data is superimposed. The dark-shaded area shows the contribution from the background as obtained by the fit to the sidebands as shown in Figure 4a). The light-shaded area shows the sum of the background distribution and the Gaussian convoluted with the exponential from b-decay. The remaining Gaussian centered at 0 (unshaded area) is due to prompt decays. The fit results in:

$$\tau_{\rm B} = 1.46 \pm 0.06 \text{ (stat.) ps and } \mathrm{f_B} = 15.1 \pm 0.6\%\text{(stat.)}$$

The fit parameter f_B obtained in the above procedure does not necessarily reflect an unbiased measurement of the fraction of J/ψ's coming from b decay. The applied track quality cuts favor isolated events therefore these cuts systematically decrease this fraction.

The systematic uncertainties on this measurement are listed in Table 1. The systematic uncertainty due to model dependence, including the b quark production spectrum, J/ψ momentum spectrum in the B rest frame, J/ψ polarization and fragmentation as well as the uncertainties associated with modelling the decay of b-baryons and higher mass b-states is 3%. The uncertainty in the decay vertex resolution has been studied using several independent datasets. Studies of a sample of prompt $\Upsilon(1S) \to \mu^+\mu^-$ events and of a sample of tracks selected from jet events indicate that the resolution function for tracks from the primary vertex is symmetric and centered at zero decay length. The uncertainty due to residual misalignment of the SVX has been studied by varying the alignment correction constants. The systematic error due to misalignment was estimated to be 2%. The beam position variations within a run have been measured to be less than 4 μm, which leads to a 1% systematic error on the $c\tau$ measurement. The effect of impact parameter bias in the CFT and Level 3 trigger gives an estimated uncertainty of 1.4%, while the systematic error due to the background parameterization was estimated to be 0.5% by varying the slope of the two exponentials in

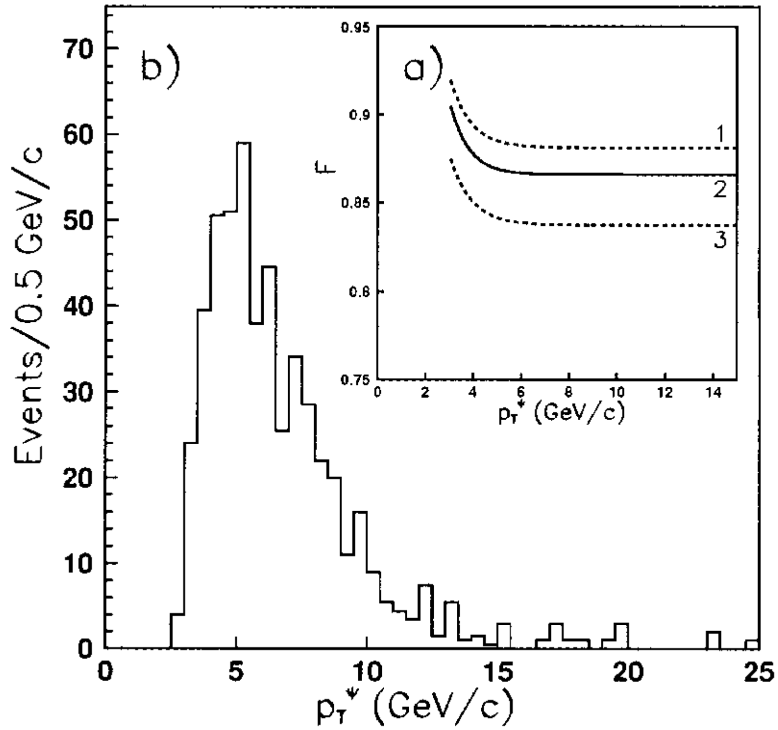

Figure 3: *a) Correction factor $F(p_T^\psi)$ with the upper and lower bands of the systematic uncertainty. b) Background subtracted J/ψ p_T-spectrum requiring $\lambda > 200$ μm.*

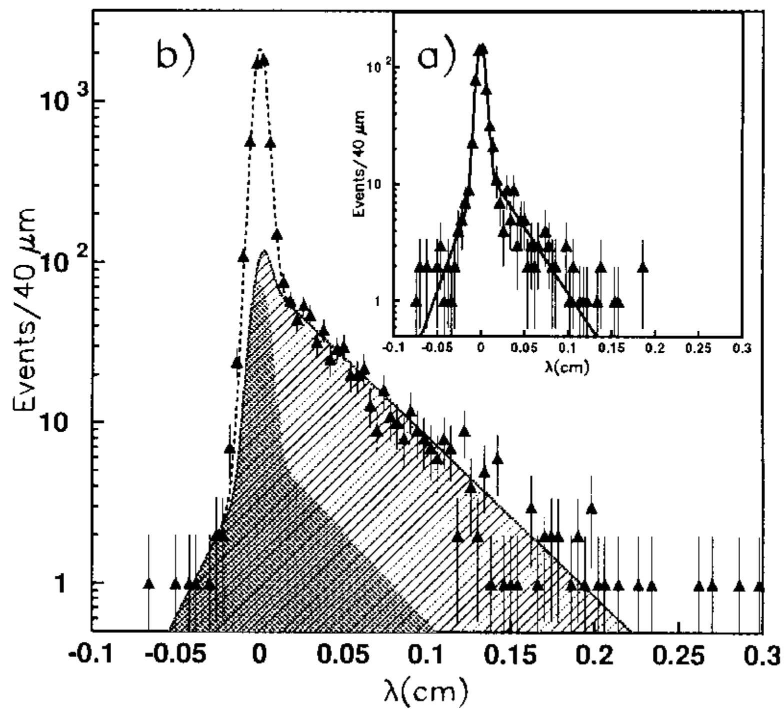

Figure 4: *a) The distribution in λ, the proper decay length, of data in the sideband regions. The solid line shows the results of a maximum likelihood fit. b) The distribution in λ of data in the signal region. The curves are the result of the unbinned likelihood fit described in the text.*

Description	Contribution
Production and decay kinematics	3 %
Residual misalignment	2 %
Beam stability	1 %
Trigger bias	1.4 %
Background parameterization	0.5 %
Uncertainty in $c\tau$ resolution	1.6 %
Total	4.3 %

Table 1: *Systematic uncertainties of the inclusive lifetime measurement.*

this parameterization by one sigma. The effect of varying the $c\tau$ error scale in the maximum likelihood fit gives an 1.6% uncertainty.

In conclusion, we have measured the average B lifetime at CDF. We find:

$$\boxed{\tau_B \;=\; 1.46 \;\pm\; 0.06\;(stat.) \;\pm\; 0.06\;(syst.)\; ps}$$

This measurement is the average over all b-hadrons produced in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV, weighted by their branching ratios into J/ψ and their production cross sections.

Table 2 shows the results of recent inclusive lifetime measurements [12] [13]. Most of them are using the lepton impact parameter to extract τ_B. Our measurement is in good agreement with these measurements. The LEP results shifted quite remarkably since 1991. At that time the average was about 1.3 ps [1]. All updated measurements are around 1.5 ps as summarized in Table 2.

Experiment	τ_b in ps
CDF (J/ψ)	$1.46 \pm 0.06\,(stat.) \pm 0.06\,(syst.)$
ALEPH (J/ψ)	$1.35 \pm 0.19\,(stat.) \pm 0.05\,(syst.)$
OPAL (J/ψ)	$1.32\ +0.31\ -0.25\,(stat.) \pm 0.15\,(syst.)$
OPAL	$1.523 \pm 0.034\,(stat.) \pm 0.038\,(syst.)$
L3	$1.533 \pm 0.035\,(stat.) \pm 0.028\,(syst.)$
DELPHI	$1.28 \pm 0.1\,(stat. + syst.)$
ALEPH	$1.49 \pm 0.03\,(stat.) \pm 0.06\,(syst.)$

Table 2: *Comparison of recent inclusive lifetime measurements.*

3 Measurement of $B^{\pm}$ and B^0 lifetimes using exclusive decays.

The relatively straightforward extraction of the lifetime is performed in three steps:

[1] see e.g. [14]

1. Reconstruct B's in the following channels:

$$\begin{array}{llll} B_u & \rightarrow J/\psi K^\pm & B_d & \rightarrow J/\psi K^0_S \\ B_u & \rightarrow J/\psi K^*(892)^\pm & B_d & \rightarrow J/\psi K^*(892)^0 \\ B_u & \rightarrow \psi(2S) K^\pm & B_d & \rightarrow \psi(2S) K^0_S \\ B_u & \rightarrow \psi(2S) K^*(892)^\pm & B_d & \rightarrow \psi(2S) K^*(892)^0 \end{array}$$

   with the subsequent decays:

$$\begin{array}{llll} \psi(2S) & \rightarrow J/\psi \pi^+\pi^- & K^*(892)^0 & \rightarrow K^\pm \pi^\mp \\ J/\psi & \rightarrow \mu^+\mu^- & K^*(892)^\pm & \rightarrow K^0_S \pi^\pm \\ & & K^0_S & \rightarrow \pi^+\pi^- \end{array}$$

2. For each candidate, compute the proper time $c\tau = L_{xy} M^B / p_T^B$, where the transverse decay length L_{xy} is obtained assuming the primary interaction vertex to occur at the center of the beam spot.

3. Fit the proper time distributions to extract the lifetimes, assuming that the background events under the signal have the same distribution as the side band candidates.

In the following the event selection and the reconstruction of exclusive final states will be described.

J/ψ selection:

The data selection is slightly different from the one for the inclusive lifetime measurement. Here the dominant error arises from the limited statistics so that strict track quality cuts to reduce the systematics originating from tails in the resolution function don't pay off. To reconstruct exclusive decays we start with a slightly bigger data sample corresponding to an integrated luminosity of 11 pb^{-1}. Since we fully reconstruct the complete B-decay chain Monte Carlo modelling of trigger and acceptance to obtain a correction factor F isn't necessary. We can also use the muons detected in the muon extension system (CMX). While the muon selection cuts are the same as described in section 2, no strict quality cuts were applied. Instead all tracks used for the B-vertex were required to be well measured in the CTC and to have either at least 3 hits or 2 nonshared hits with a χ^2 of less than 8 in the SVX. This results in a sample of 19165 $\pm$ 107 J/ψ events. The mass resolution returned by the fit is 17 MeV/c^2. The signal region is defined as $\pm 80 MeV/c^2$ around the J/ψ-mass.

$\psi(2S)$ selection:

$\psi(2S)$ mesons are reconstructed via the decay $\psi(2S) \rightarrow J/\psi\pi^+\pi^-$. The vertex- and J/ψ mass-constraint fit to the four tracks was required to have a χ^2 -probability prob(χ^2) $> 1\%$ and to have a momentum of more than 3 GeV/c. The invariant mass of the $\pi^+\pi^-$-pair was required to be less than 0.6 GeV/c^2 and finally the invariant mass of the four tracks had to be within 20 MeV/c^2 around the world average $\psi(2S)$-mass (3.686 GeV/c^2). The selected sample consists of 344 $\pm$ 43 $\psi(2S)$ events. The decay mode $\psi(2S) \rightarrow \mu^+\mu^-$ hasn't been used yet but will be in the near future.

Kaon selection:

$K^0_S \rightarrow \pi^+\pi^-$ transitions were identified by requiring the vertex to be displaced from the primary vertex. For the vertex constrained fit we required prob(χ^2) $> 1\%$; $c\tau$ had to be greater than 0 and the invariant mass $m_{\pi\pi}$ had to be within 20 MeV/c^2 of the K^0_S mass.

For $K^*(892)^\pm \rightarrow K^0_S\pi^\pm$ candidates prob(χ^2)$>$ 1% was required for the vertex and mass constraint fit, the invariant mass of the $K^0_S\pi$ had to be within 80 MeV/c^2 of $m_{K^*(892)^\pm}$.

The invariant mass of $K^*(892)^0 \rightarrow K^\pm\pi^\mp$ candidates was required to be within 80 MeV/c^2 of $m_{K^*(892)^0}$.

Parameter		Fit results	
		Charged B	Neutral B
$\lambda = c\tau$	$[\mu m]$	488 ± 63	462 ± 67
α	[%]	33 ± 3	18 ± 2
n_B	[events]	75 ± 10	61 ± 9
f^-	[%]	6 ± 4	1 ± 1
λ^-	$[\mu m]$	38 ± 15	134 ± 87
f^+	[%]	5 ± 2	10 ± 2
λ^+	$[\mu m]$	154 ± 50	86 ± 13
Lifetime ratio $= \tau^\pm/\tau^0 = 1.06 \pm 0.20$			

Table 3: Result of fit to the proper $c\tau$ distributions of the exclusive decays.

Putting it all together:

All reconstructed Kaons ($K^\pm$, K_S^0, $K^*(892)^0$ or $K^*(892)^\pm$) are required to have $P_t(K) >$ 1.25 GeV/c. Finally all charged tracks except tracks from K_S^0 were vertex and mass constraint to the J/ψ,$\psi(2S)$. In the case of a K_S^0 we performed a vertex and mass constrain fit to the K_S^0 and applied a pointing constraint to the B vertex. For each fit we required prob(χ^2)> 1%. For the reconstructed B we required $P_t(B) > 6.0\ GeV/c$.

The signal region was defined as 30 MeV/c^2 around the B-meson mass. The sideband regions are the mass regions between 60 and 120 Mev/c^2 above and below the B-mass.

To fit the $c\tau$-distributions and to extract the lifetime we assume that the $c\tau$-distribution of the background has the same shape as the sidebands. The proper $c\tau$-distribution of the sidebands and the background in the signal region is parameterized as a Gaussian resolution function plus exponential tails (fractions $f^\pm$ and slopes $\lambda^\pm$). The signal (n_B events) is parameterized by an exponential (slope λ) convoluted with a Gaussian resolution function where the sigma is the error as calculated event by event. The unbinned fit is performed simultaneously on the signal and sideband regions constraining the number of background events (fraction $1-\alpha$) to be, within Poisson fluctuations, equal to the number of events in the sideband regions normalized to the same invariant mass interval as the signal. The result of the fit is summarized in Table 3. Figures 5 and 6 show the proper $c\tau$ distributions for charged and neutral B-mesons with the fit superimposed as well as the proper $c\tau$ distributions of the sidebands.

Table 4 summarizes the systematic uncertainties on this measurements. The errors related to misalignment and trigger bias are the same as for the inclusive lifetime measurement. Since the decay is fully reconstructed there is no error due to model dependences, instead the dominant systematic errors come from the uncertainty in the background shape ($\approx$ 10%) and resolution function ($\approx$ 5%). This is due to the fact that the background fraction in these samples is bigger (70 to 80% compared to 5.7 %) and that the track requirements are less strict. There are also a couple of events in the sideband region which seem to be displaced from the primary vertex and which are not very well accounted for in the fit. Overall the total error is dominated by statistics rather than by systematics. After the full present data set has been used, we expect:

$$\text{systematic uncertainties} \ \leq \ \text{statistical uncertainties} \ \leq \ 15\%$$

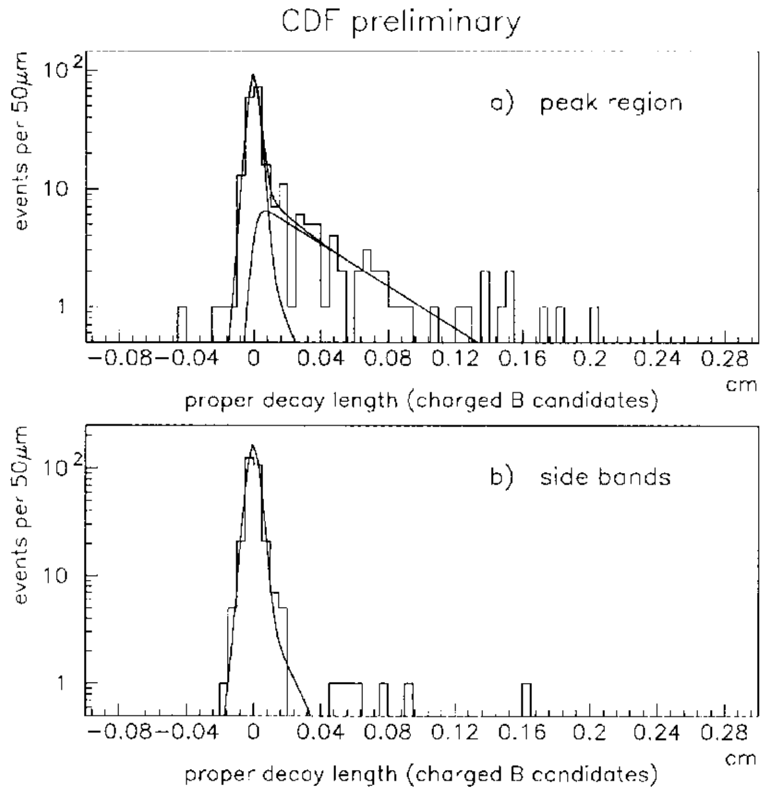

Figure 5: *Proper-cτ-distribution of neutral B-candidates. The result of an unbinned likelihood fit is superimposed.*

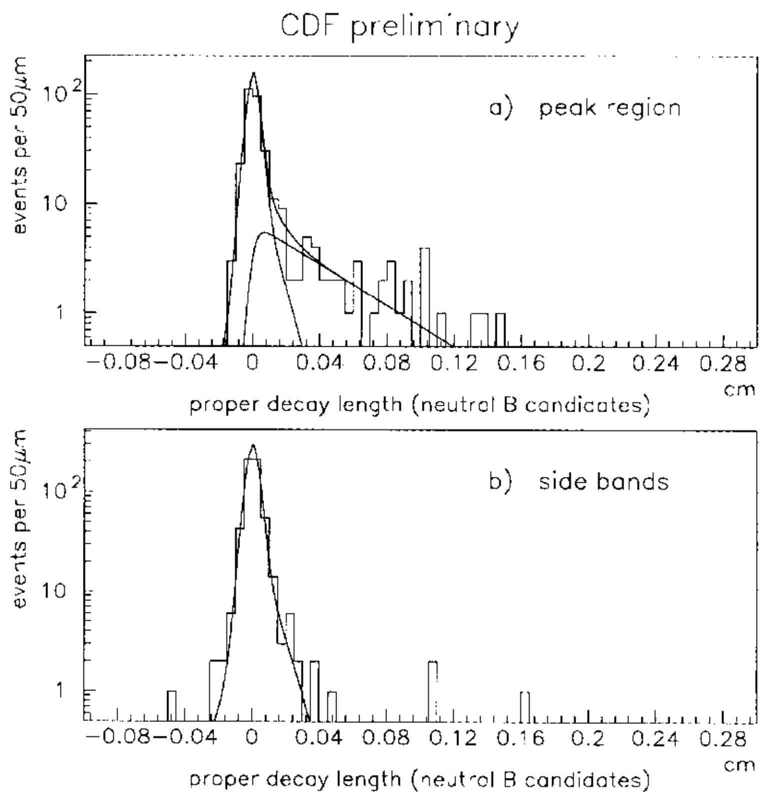

Figure 6: *Proper-cτ-distribution of neutral B-candidates. The result of an unbinned likelihood fit is superimposed*

Description	$B^{\pm}$	B^0
Residual misalignment	10 μm	10 μm
Trigger bias	6 μm	6 μm
Beam stability	5 μm	5 μm
$c\tau$ resolution	10 μm	10 μm
Fitting procedure bias	5 μm	5 μm
Background shape	45 μm	25 μm
Total (preliminary)	48 μm	30 μm

Table 4: *Systematic uncertainties of the exclusive lifetime measurement.*

In conclusion using $\sim 1/2$ of the data collected up to now, we obtain:

$$\tau^{\pm} = 1.63 \pm 0.21\,(\text{stat}) \pm 0.16\,(\text{syst})\; ps \quad (\text{preliminary})$$

$$\tau^{0} = 1.54 \pm 0.22\,(\text{stat}) \pm 0.10\,(\text{syst})\; ps \quad (\text{preliminary})$$

$$\tau^{\pm}/\tau^{0} = 1.06 \pm 0.20\,(\text{stat}) \pm 0.12\,(\text{syst}) \quad (\text{preliminary})$$

4 Measurement of the B_s^0 meson lifetime

One possibility would be to use the decay $B_s \to J/\psi\phi$ [15] but for this mode the statistics is limited. Instead we partially reconstruct the semileptonic decay $B_s \to l\nu D_s^+$ by identifying events where a D_s^+ is associated with a lepton. Some momentum is carried away by the neutrino which has to be corrected for with a correction factor $K(P_t) = P_t(lD_s^+)/P_t(B_s)$ obtained from Monte Carlo calculations. The D_s^+ has a finite lifetime resulting in an additional vertex displaced from the B_s vertex. To estimate the B-vertex in the $r\varphi$-plane we first reconstruct the vertex and the transverse momentum of the D_s^+. Then we extrapolate its trajectory back to where it intersects with the trajectory of the lepton.

Thus the best estimate of the proper time of the B decay is:

$$c\tau^* = \frac{L_{B_s} \cdot m_{B_s}}{p_t(lD_s^+)} K$$

The selected data sample consists of approximately 13 pb^{-1} of electrons with $E_t > 6$ GeV and about 13.5 pb^{-1} muons with $P_t > 6$ GeV/c corresponding to $\approx 4 \cdot 10^5$ candidates of each lepton type. The D_s^+ are identified from the decay $D_s^+ \to \phi\pi^+ \to K^+K^-\pi^+$. Any oppositely charged track pair is used to form a ϕ candidate, where each kaon candidate is required to have $P_t > 0.8$ GeV/c and to be within a cone of $\sqrt{\Delta\eta^2 + \Delta\varphi^2} < 0.8$ around the lepton. A ϕ candidate is accepted when its mass is within $\pm$ 8 MeV/c^2 and its P_t is above 2.0 GeV/c. Then we combine an additional track which has a charge opposite to the lepton charge to form a D_s^+. These three tracks are then vertex constrained requiring $\chi^2 < 15$ for 3 d.o.f. To reduce combinatorial background we require $|\cos\psi| > 0.4$ where ψ is the helicity angle between the K^+ and the D_s^+ in the ϕ rest frame. This cut removes 40% of the flat background and keeps 93% of the signal.

To provide a check the decays $B \to l^- D^0 X$ and $B \to l^- D^{*+} X$ were reconstructed in a similar fashion. Figure 7 shows the invariant mass distributions for $D^0 \to K^-\pi^+$ and

$D_s^+ \to \phi\pi^+ \to K^+K^-\pi^+$ candidates. The signal and sideband regions are indicated. We find 41 ± 6 D_s^+ events and 251 ± 15 D^0 events. Figure 8 shows the $c\tau^*$-distribution of l^-D^0 (upper plot) and $l^-D_s^+$ (lower plot) events with the result of an unbinned likelihood fit superimposed. The fit results as well as D-lifetime results extracted from this data are summarized in Table 5. The systematic uncertainties are summarized in Table 6.

$c\tau_{B_s^0}(B_s^0 \to l\nu\ D_s^+)$	$461^{+125}_{-101}\ \mu m$
$c\tau_B(B \to l\nu\ D^0X)$	$466^{+48}_{-45}\ \mu m$
$c\tau_B(B \to l\nu\ D^{*\pm}X)$	$441^{+55}_{-50}\ \mu m$
$c\tau_{D_s^+}(D_s^+ \to \phi\pi^+)$	$210^{+75}_{-67}\ \mu m$
$c\tau_{D^0}(D^0 \to K^+\pi^-)$	$160 \pm 32\ \mu m$

Table 5: *Lifetime fit results.*

Description	Contribution
Resolution function	$\pm$ 3 μm
Background shape	$\pm$ 12 μm
Decay length cut	- 10 μm
Fitting method	$\pm$ 6 μm
Production and decay kinematics	$\pm$ 19 μm
Uncertainty in $c\tau$ resolution	$\pm$ 20 μm
Residual misalignment	$\pm$ 9 μm
Physics background	$\pm$ 11 μm
Total (preliminary)	$\pm$ 35 μm

Table 6: *Systematic uncertainties of the B_s^0 lifetime measurement.*

In conclusion, we have measured the B_s^0 lifetime and find the following value which is consistent with LEP results [16].

$$\boxed{\tau_{B_s^0} = 1.54^{+0.42}_{-0.34}\ (stat.) \pm 0.12\ (syst.)\ ps \quad \text{(preliminary)}}$$

5 What's next?

Up to now only about 50 % of the present data has been used for the measurements reported in this article. Processing the rest of it is under way especially the exclusive and semiexclusive lifetime measurements will benefit from doubling the statistics. The only obstacle is the fact that in the late part of the run radiation damage somewhat degraded the performance of the innermost SVX layer. Here one has to be careful in combining the samples.

The inclusive measurement which has already been submitted for publication will also be performed with higher statistics. Improved measurements of the J/ψ- polarization and the J/ψ-momentum spectrum in the B-restframe are now becoming available from CLEO II, as well as measurements of the differential $b\bar{b}$ cross section at the Tevatron. The hope is that the

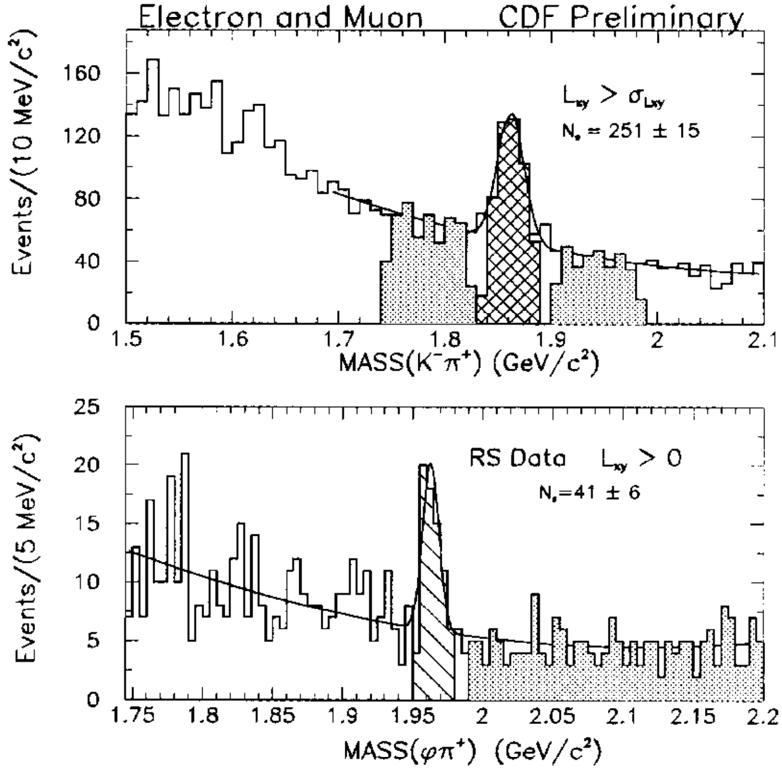

Figure 7: *Invariant mass distributions for* $D^0 \to K^-\pi^+$ *and for* $D_s^+ \to \phi\pi^+ \to K^+K^-\pi^+$ *candidates.*

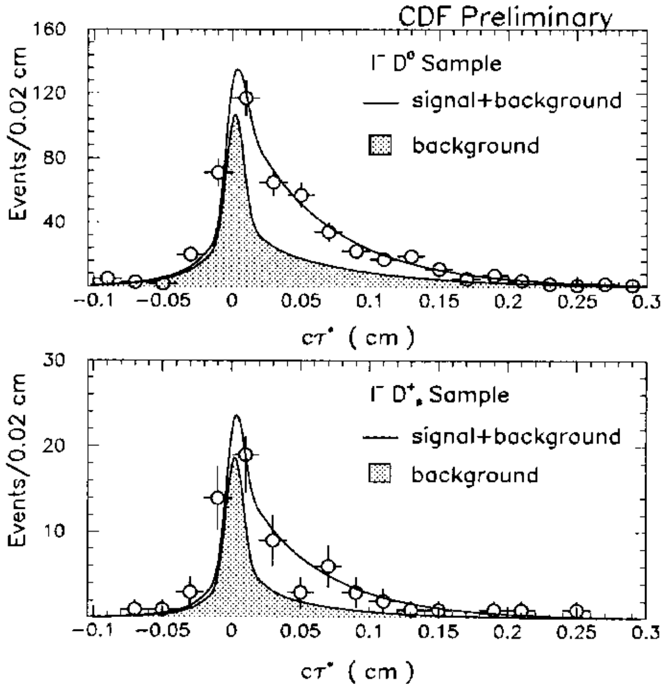

Figure 8: $c\tau^*$*-distribution of* l^-D^0 *(upper plot) and* $l^-D_s^+$ *(lower plot) events with the result of an unbinned likelihood fit superimposed.*

systematic error linked to the production and decay kinematics will be reduced. In addition we will measure the time dependence of $B_d\bar{B}_d$ mixing.

In November 1993 a new run (Run 1B) will start. The goal is to increase the current dataset to a total of 100 pb^{-1}. To deal with this high luminosity CDF has been equipped with a new silicon vertex detector SVX' which is radiation hard and which has a much better signal to noise ratio than its successful predecessor.

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